# Statement of Research

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## General Introduction

**PhD Degree**: I am pursuing my PhD degree at Kansas State University. I have been working in the High Energy Physics Group under the supervision of Professor Tim Bolton, and have been in the CMS collaboration since 2007. As a part of the CMS collaboration I am involved in the efforts of the $V\gamma$ group studying di-boson production. My PhD thesis analysis is the study of the helicity distributions in the $Z\gamma$ production at the CMS experiment. I did most of my research while being stationed at Fermilab, where I highly benefited from the intellectual recourses.

**Masters Degree**: I got my masters degree in Solid State Physics at Tbilisi State University for studying the properties of wide band gap semiconductors (predominantly $ZnO$, $ZnS$) and ways to invert their type of conductivity. I participated in the process of growing wide band gap semiconductor crystals for our research and studying different ways of crystal growth and cutting.

## Research Interest

The most exciting part that attracts me to the research in the high energy physics is the search for fundamental building blocks of the universe and new laws of nature. My research interests include searches for physics both within and beyond the Standard Model. Recent discovery of the Higgs boson is a major breakthrough in the particle physics, but there is still work to be done in that direction. Having experience in the di-boson physics analysis at the CMS, which is one of the cleanest and strongest signals for the Higgs discovery, makes Higgs analysis the natural interest of mine. My current study involves the analysis of the $Z\gamma$ production using full kinematic information. Performing similar analysis on the Higgs di-boson decay channels can answer the questions about the properties of the recently discovered boson. The involvement of the Northwestern group in electroweak, Higgs and beyond standard model physics are very close to my current and future interests. The analysis skills I acquired while working on di-boson physics at the CMS are fundamental and transferable and I believe can contribute to the efforts of the group.

## Research Statement

Modern high energy physics experiments are a complicated synthesis of the *theory* behind an experiment, design and development of the *detector* to conduct the experiment, *monitoring* of every detail of the extremely complicated detector, and *analysis* of the obtained data. I am lucky to have worked on various aspects of the CMS experiment. I had an opportunity to work on the pixel detector, develop tools for online monitoring and, of course, do the interesting analysis of the data collected by the CMS.

**My Analysis**: In my analysis I study the di-boson production of neutral gauge bosons and look at the helicity distributions in the data obtained from the hadron-hadron collisions at the LHC. This analysis has not previously been performed at a hadron collider and it is very interesting for probing the trilinear anomalous gauge couplings. While a more natural choice of the analysis for a grad student, when the LHC and CMS were still getting ready for the first collisions, would have been a standard model cross-section measurement analysis in collaboration with CMS working groups, I decided to tackle a more elaborate analysis that has not yet been performed. I am the leader and the working group of this analysis, which is very unique within the CMS collaboration. I took the challenge and while similar analyses are just now gaining priority at the CMS, my analysis is ready and spearheading the efforts in this direction.

I used the helicity formalism to theoretically calculate the angular distribution of the final state particles (leptons and a photon), for the $Z\gamma$ production, as a result of the quark-quark scattering. Using unbinned likelihood method, for the distribution function obtained, I measure the helicity amplitudes for the process. In contrast to the conventional ATGC analysis, my analysis provides the sensitivity to the sign of the measured parameters, due to the interference of the different helicity states. The helicity amplitudes are very precisely predicted in the Standard Model and any deviation of the measured results from the theoretical predictions could indicate presence of couplings between gauge bosons, which are not allowed by the electroweak theory.

It was only natural for me to do the related $Z\gamma$ analysis, so I have worked with the CMS $V\gamma$ analysis group. Our group measured the $Z\gamma$ and $W\gamma$ production cross-section and set the limits on the anomalous couplings between the gauge bosons. I heavily contributed to the cross-check of the correctness and consistency of the entire chain of analysis in all four channels ($Z(ee)\gamma$, $Z(\mu\mu)\gamma$, $W(e\nu)\gamma$, $W(\mu\nu)\gamma$). I also performed the studies on many Monte Carlo (MCFM, MadGraph, BAUR, Sherpa) generators for di-boson production processes.

My particular analysis proved to be very interesting while working with the Monte Carlo generators, as well. I have uncovered a bug [bug 1078168] in the MadGraph generator, discovery of which required the angular analysis that I am performing for my helicity analysis.

**WebBased Monitoring**: My interest in programming and programming languages far precedes their need in my physics data analysis. I have been programming using low level (basic/pascal/C) and later high level (C++/java/etc.) programming languages and developing complicated algorithms starting from my high school years. Software skills enabled me to quickly integrate into the efforts of the WebBased Monitoring (WBM) team. In my projects, I used C++ with ROOT libraries to construct the necessary plots. Java platform and Java servlets were used for publishing the dynamic content on the web pages. Information for the monitoring tools were fetched from different messaging systems and the Oracle database.

I developed web based tools to monitor the performance of the LHC and CMS detector. These tools enable experts of individual subsystems to have a full, summarized and concise information in near-online regime to quickly gather the vital information and/or respond to the challenges of the detector or other supporting hardware (e.g. vacuum, power supply) or software (e.g. high level triggering). One of my early projects was CMS Page1, which shows current status of the detector and the data collection. Page1 is one of the few CMS technical pages that is available for public: `http://cmspage1.web.cern.ch/cmspage1/`.

*FillReport* and *DataSummary* are two of my projects that are very heavily used for Run Coordination and monitoring the vast amount of details of the experiment during each LHC fill and broader periods of time. These tools provide vital online, as well as archival, information regarding the CMS and LHC performance. Each summary page provides the possibility to drill down to every detail of every LHC Fill and CMS Run.

My experience in software development and skills acquired during my work on such a big experiment as CMS, makes me confident that I can be a valuable asset in designing and developing challenging software infrastructure for high energy physics experiments.

**Hardware Experience - CMS Pixel Detector** : My first experience with the CMS pixel detector was testing of the detector endcap modules at Fermilab. Later, as a part of the Partnerships in International Research and Education (PIRE) project, I had the opportunity to have a hands-on experience with the CMS pixel detector at Paul Scherrer Institute (PSI), Switzerland. While working with PSI team, I had a great opportunity to observe and study the detector firsthand. I worked on the commissioning of its barrel part. During testing and commissioning I had hands-on experience with all the details of the detector, architecture of individual modules, digital and analog converters, front-end electronics and software. I developed and optimized software tools (pixelOnlineSoftware, part of xDAQ Software) for testing and commissioning purposes (implemented easy visualization schema for testing, added necessary reset options for the proper initialization of the pixel detector, etc.). After the insertion of the pixel detector into the core of the CMS in 2008 I was very closely working with the pixel detector team to properly calibrate the detector and study its performance.

The biggest challenge during my work at PSI was related to the detector upgrade project. Part of this upgrade is the increase of the digital output size from current 4 bits to 8 bits. I was assigned the task of studying the challenges of simple extension of the current analog to digital converter (ADC) to 8 bits and developing the new possible design. I was able to identify the problem of the 8 bit architecture at hand and probable culprit. To design and test the new ADC I used electronics design software, CADANCE, and started working on possible 8 bit implementation. My 8 bit ADC was utilising the current 4 bit design with addition of the very precise current divider.

Working on the pixel detector was a confidence building experience to tackle the detector related challenges in the future.

## Summary

As a major developer and author of my thesis analysis, I have acquired very strong skills to work independently. On the other hand, working in a big collaboration such as CMS, has enhanced my team-work experience. My diverse background in physics, and broad experience in the field of high energy physics with the CMS experiment, have laid a solid ground for me to further pursue an academic career. I am confident that I can contribute to the efforts of your group, both, in the physics analysis and addressing the hardware and software needs of the experiment. My ambition is to be a part of the processes that would lead our understanding of physics to a goal of "fitting physics easily on the front of a T-shirt"(L.Lederman).